KESS: Knowledge Engineering Support System

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ABSTRACT

KESS (Knowledge Engineering Support System) is a relational information management system created at the University of Utah to document each step in the building of four expert knowledge bases. In weekly knowledge engineering sessions, groups of experts propose decision making criteria and examine information sources in the process of creating HELP knowledge frames. KESS utilizes many-to-many links with multiple files and central link files to track the different kinds of information generated and used in the four knowledge building projects.

INTRODUCTION

Building an expert system in medicine is a difficult, time-consuming job[1,2,3,4]. It involves many meetings of people from various disciplines. In each of the sessions, statements about the relationships used in decision-making are made by experts, data is examined from medical literature and hypothetical relationships are tested against local patient data bases. In order to maintain continuity and provide future reference to this process, a relational information management system known as KESS (Knowledge Engineering Support System) was created. It is the purpose of this paper to describe this data base and it's use at the University of Utah.

BACKGROUND

In conjunction with the National Library of Medicine IAIMS (Integrated Academic Information Management System) project[5,6], the University of Utah School of Medicine, Colleges of Nursing and Pharmacy and the Eccles Health Sciences Library have been building knowledge bases in the subject areas of anemia, bone tumors, nursing management of pain and antibiotic selection. The knowledge bases are being built in the form of decision frames for the existing HELP (Health Evaluation through Logical Processes) system[7,8], at LDS and University Hospitals in Salt Lake City. KESS tracks the knowledge represented in a frame and the frame's relationship to information sources used in creating the frame. The information sources are experts, literature references and local patient data bases.

The frame building process occurs in weekly meetings of groups of individuals representing a variety of expertise. There are experts in hematology, nursing, clinical pharmacy, pathology, radiology and orthopedic research. Experts in the HELP system participate by providing information on local patient study populations. Librarians interactively discuss information retrieved from literature searches and analyses. Graduate students in the Department of Medical Informatics also participate in the sessions and write the actual decision frames.

During a weekly session for the anemia group, the project director and principal knowledge engineer, Dr. Homer Warner, queries the clinical expert as to how he would approach the problem at hand. The hematologist follows by defining the disease set or other topic to be discussed and lists significant criteria to be included in the specific decision frames. He also describes interrelationships and conditions for the criteria and provides estimates for disease prevalence, sensitivity and specificity and laboratory threshold values[7]. This quantitative data is used to calculate probabilities for specific HELP knowledge frames. As the knowledge engineer logically connects the criteria, the expert provides feedback as to the frame's accuracy. In this process, expert knowledge modeling is reflective and interactive. Thoughts are expressed, mulled over, refined, withdrawn and replaced. At the end of each session, assignments are made for the next meeting. These include providing a problem-specific patient data base, locating relevant literature and constructing one or more preliminary HELP frames.

The next meeting begins with a review of the previous session's subject matter. The group now has additional information with which to react. The proposed frame may have to be altered. For example, the hematologist may have reflected on what was stated in the previous session and suggest revisions, the patient data in the study population may not agree with the previously decided upon criteria, or perhaps the literature search indicated that some of the criteria were not substantiated in certain clinical studies. A determination then needs to be made by the expert as to which source of information to use in revising the frame: experience, studies of populations that might not match local populations, or the local patient data base which has incomplete data for all patients with the disease. As the session proceeds into the current topic of discussion, several types of questions may be asked:

"What was our source for this sensitivity figure?"

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"What were the parameters of the local patient study data base?"
"Let's see our completed anemia frame again."
"What was the date of the last revision?"
"What did that article have to say about...?"
"I forgot--what was I supposed to do for this meeting?"

This overview of several anemia sessions presents the role of the principal players and the variety of information used and generated in the knowledge building process. Each of the four projects has unique aspects with regard to experts and their roles, approaches to their topics, and the type of information used.

1) In the Hematology Project, the effort was to develop frames which contained the minimal conditions for diagnosing a syndrome or disease.
2) For the "Bone Tumors " project, the group extracted data from orthopedic textbooks and reformatted, in tabular form, information on sensitivity and specificity for each tumor as a function of bone location and patient age. These discussions were led by experts from pathology, orthopedics, radiology and medical informatics.
3) In the pharmacy project, experts focused on the role of pharmacists in suggesting the appropriate dosage of antibiotics to treat an infection. Case studies from the University of Utah Medical Center helped the pharmacy expert in gathering data and extracting prototype decisions. These models served as a basis for frames implemented on the computer.
4) The nursing project focused on pain management. The nurse expert concentrated on describing the components of pain using her experience and relevant literature. Case studies of post-operative patients from orthopedic wards also provided material for discussion.

In summary, the knowledge building process begins by listing criteria and collecting quantitative data from expert estimates, medical literature and sample patient populations. The information is reviewed for entry into the HELP frame Bayesean probability calculations. The frames are then tested against study patient files. Frames are finally reviewed and revised as deemed necessary.

KESS, KNOWLEDGE ENGINEERING SYSTEM

When the knowledge building process began, KESS was perceived as a means of documenting decisions made in the meetings. As the process evolved, so did KESS. Maintaining records of the meetings became one of the first steps to a more comprehensive information management system. To fit a growing set of needs it was determined that the data base system must possess the following properties:

- Ability to enter and validate data on-line
- Expandability for a growth of information
- Adaptability to different settings (projects)
- Easy to use
- Variability in sorting and reporting of information
- Features useful for managing and updating frames

A relational data base model was selected because it could adequately document the knowledge building sessions with a minimum of data entry. In a relational data base, numerous files exist, each recording a particular type of information. Examples of relational files in KESS include a meeting notes file, an expert file and a knowledge frame file. Records in these files are related by entries in a "link" file. In a relational data base a particular data item is entered only once. Additional references to that item are recorded via links to seperate data files. For example, experts' names are not entered into meeting notes each time they attend a knowledge building session. Their relationship to the meeting (attendance) is documented by adding a record to the link file (figure 1). This particular link file connects the meeting notes file with the expert file. In this manner, information on an expert is entered only once. Link file records are much smaller than expert information file records (three bytes for the link vs one byte per character to store the name, phone number, address, etc.) thus making efficient use of computer meeting and an expert than to type the expert's name into the notes for each meeting attended. Other KESS files are "linked" in similar fashion.

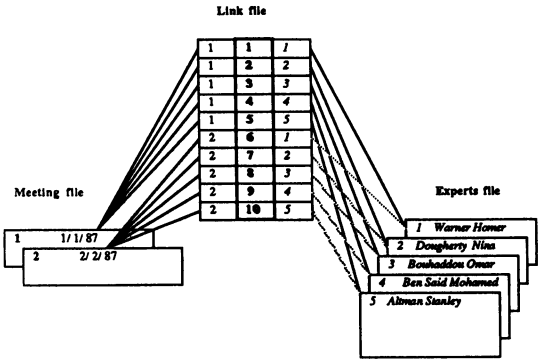

Figure 1. One record in the link file points to two records, each from the connected files

The Apple Macintosh® was chosen because it is user friendly and a good educational tool. To reduce development time and address immediate needs, a commercial data base management system was purchased. Of the data base programs available, OMNIS 3 Plus®[9,10] was selected because it was the most powerful and flexible relational data base available for the Macintosh.

Components of Omnis 3 make data entry and retrieval easy. Display screens on the Macintosh may be drawn in a manner natural and logical to the user. Developer defined menus and active areas of the screen known as "buttons" allow the user to initiate complex algorithms with ease. Editing, updating, adding and finding records are functions performed by selecting labeled buttons. These and other complex functions are defined with "sequences" (macros). Sequences can be written to display records in scroll rectangles, define and use interactive portions of the screen and establish relationships between files.

As a relational data base, Omnis 3 allows files to be "linked". It is these links that keep track of the relationships between files. KESS utilizes many-to-many links. These occur when a special link file is used to track relationships between one or more entries in one file with one or more entries in another file. To expand on the previous example, a many-to-many relationship could track all meetings attended by a particular expert and/or report on all experts who attended a particular meeting.

Files in the current and forthcoming versions of KESS include:

- Expert File:

Contains name, address, telephone number and brief curriculum vita for each member of a project team.

- Meeting File:

Short, precise textual record of decisions and discussion that occurred during a meeting.

- Action Item File:

Record of assignments made to individuals. Includes date assigned and status.

- Clinical Criteria File:

Contains, in prose, the rationale for the criteria used, or not used, in a specific frame.

- Knowledge Frame File:

Contains the most current version of each knowledge frame formulated by the group. Includes latest revision date, code number, owner and author, title, purpose, type, status and frame items in a textual format.

- Nested Frame File :

Created to respond to a newer approach to structuring knowledge frames in the system: nested frames where an item in a frame "calls" another frame, or frames, to be executed. This file contains the "called" frames.

- Patient Data File:

Descriptions of local patient study populations used in developing the frames. Includes date, time period, size, location of patients, selection parameters and specified data for patients with a disease or finding.

- Literature File:

Records references to and extracted information from articles and other literature.

- Table File :

Contains a table code. Used to create tables of data extracted from other files.

- Value File :

Contains numerical and text fields. Used in importing tables or other formatted data from different software.

- Index Term File :
A file of single and multi-word index terms created primarily to retrieve meeting records, frames and the literature by subject matter.

- Link Files :

- Knowledge Frame Link File :
Documents relationships between frame file and the nested frame, literature, patient data, clinical criteria, table, index terms and expert files.

- Meeting Link File :
Connects the meeting, expert, index terms, action items and frame files. Retrieves the names of the experts participating in a meeting and their assignments.

- Table Link File :
Used to create tables based on relationships among the index terms, values, table code and patient data files.

- - Temporary file :
Provided by the program itself. Contains fields holding temporary values.

Since it's inception, KESS has passed through several evolutionary cycles. Some of these changes were due to concurrent changes in the process of knowledge base development. Other changes were conceptual in nature and developed as expertise in Omnis 3 was achieved.

The concept of a "central link" file was one of the feature enhancements. Through use of a central link file, KESS can combine information from several different files for display in one report. For example, it is possible to list uncompleted action items sorted by related expert and meeting date.

KESS expands the central link idea to organize information into sets covering related information needs. Three central link files are used to categorize information according to file relationships and reporting needs (figure 2). The first of these was built around documenting the knowledge frame. Included in the knowledge frame link file are pointers to the knowledge frame, nested frame, literature, patient data, expert, index term, and clinical criteria files. The second central set is related to the meeting. It links the meeting file to the experts who attended, the action items addressed, the topics (index terms) and the knowledge frames discussed. To enhance data understanding, a third set was conceived to manage data in tabular form.

Another important aspect of the KESS data base is the creation of a separate literature file to store information sources researched but not necessarily used in the actual knowledge frames. This interim literature file is available for on-line searches during knowledge building sessions. It manages the literature selected for potential usefulness and gives the knowledge building team an indexed medical reference at their finger tips. KESS researchers are working on expanding this important feature.

Two methods exist for accessing information in the KESS data base. The simplest way is to use Omnis 3 functions such as *find, next* and *previous*. The second method is accessing information via the central link files. For example, the hematology expert may want to see the frame related to hemolysis. A pull-down menu entitled "Search Frame" lists the different ways in which the frame may be located, such as by index term or frame number. He selects "Index Term" and enters "hemolysis". The hemolysis frame will then be displayed.

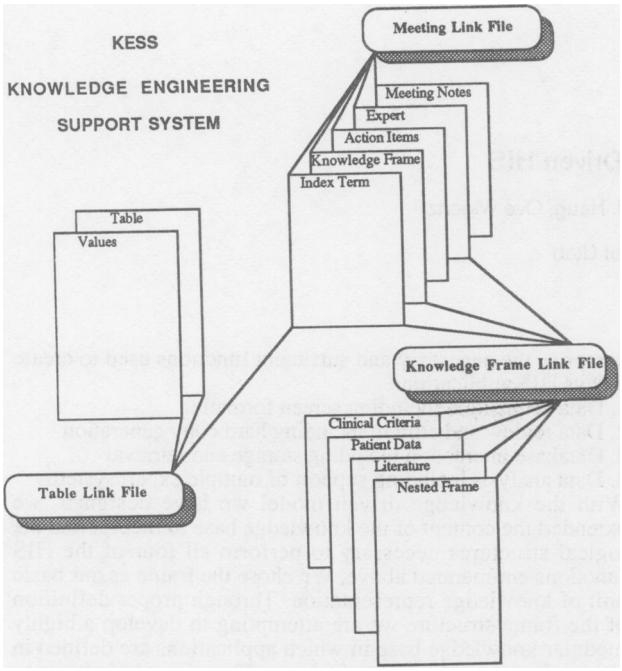

Figure 2. Design of four central link files to manage information in the knowledge base building process

USE OF KESS

KESS is used on-line in the four knowledge engineering meetings to document the discussions and decisions made during the sessions. In addition, it records assignments for the next meeting. The individual entering the textual information in the meeting record can at any time call up other files to answer questions raised by the participants or to revise old data. Frames can also be refined and updated in a on-line manner. At the end of each session a printout of the meeting record is available for each team member. Literature citations and descriptions of patient data bases are usually entered into the KESS data base between meetings.

CONCLUSION

KESS is an information management system based on a relational database model which eliminates multiple data entry and allows easy data modification. It also allows easy data retrieval by searching through a single file or a relation between many files. It was initially created to document knowledge sources such as the medical expert, patient database or literature. As the process advanced, KESS was used to allow on-line entering and revising of synthesized notes. It was also adapted to contain and update knowledge frames developed in the sessions. The evolution toward documenting the knowledge engineering discussions helps retrace the decision making process and provides basic material to refine methods for knowledge elicitation. It also puts some insight on the information processing and decision making mechanisms used by the domain expert.

The projected users are current and future knowledge frame builders, those using it to research clinical information mentioned in the frames, researchers interested in the knowledge engineering process itself and users wanting to know what evidence exists for decisions made in the frames.

About OMNIS 3 Plus

Omnis 3 Plus is a relational data base management system used to create user-specific, turn-key data management applications. Data file size and number of records are limited to available disk space, up to 160 megabytes. Compared with other data base programs for the Macintosh, Omnis 3 Plus offers much greater flexibility. The Omnis 3 applications developer uses the flexibility to design specialized user friendly data base management systems. While Omnis 3 systems are typically easy to use, learning the techniques necessary to program and develop them is time-consuming and difficult. The learning process can be facilitated via beginning and advanced training courses offered by Blyth Software. Several "how to" books[11,12,13] on Omnis 3 are also available. Blyth is also working on an improved, easier to develop version of Omnis 3. This version uses icons and other user interface tools in an effort to reduce the large Omnis 3 learning curve.

Omnis 3 Plus retails for $495 and is offered by Blyth Software Inc., 2929 Campus Drive, Suite 425, San Mateo, California 94403 (415) 571-0222. It can be purchased from software discount houses for less than $300.

REFERENCES

(1) Buchanan B.G. et al. Constructing an expert system. In: Hayes-Roth F., Waterman D.A., Lenat D.B., eds. Building expert systems. Reading, MA: Addison-Wesley; 1983: 127-67.
(2) Szolovits P., ed. Artificial intelligence in medicine. Boulder, CO: Published by Westview Press for the American Association for the Advancement of Science; 1982.
(3) Brooking A.G. The analysis phase in development of knowledge-based systems. In: Gale W.A.,ed. Artificial intelligence and statistics. Reading, MA: Addison-Wesley, 1986:321-34.
(4) Mittal S., Dym C.L Knowledge acquisition from multiple experts. In: Proceedings of the IEEE workshop on principles of knowledge-based systems. Denver: IEEE; 1984:75-88.
(5) Warner H.R.,Detmer D.E., Peay W.J. IAIMS implementation and administration at the University of Utah. In: Orthner H.F., ed. Proceedings of the Tenth Annual Symposium on Computer Applications in Medical Care. Washington,DC: IEEE; 1986:111-13.
(6) Matheson N.W., Cooper J.A.D. Academic information in the academic health sciences center: roles for the library in information management. Journal of Medical Education. 1982; 57(10 pt 2).
(7) Warner H.R. Computer-assisted medical decision-making. London: Academic Press; 1979.
(8) Pryor T.A., Gardner R.M., Clayton P.D., Warner H.R. The HELP system. Journal of Medical Systems. 1983; 7:87-102.
(9) Saffady, W. OMNIS 3. Library Technology Reports. 1987; 23:141-147.
(10) Rogan J. OMNIS 3 Plus - What is it? Who needs it? The MACazine. 1987; 4:32-34.
(11) OMNIS 3 Plus reference manual. San Mateo, CA; Blyth Software.
(12) Mosich D. Complete guide to OMNIS 3. Glenview, IL: Scott,Foresman: 1987.
(13) Maller S. Mastering OMNIS 3. Blue Ridge Summit, PA: TAB Books:1986.